THE DRAINAGE OF VILLAGES

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PREFACE TO THE SECOND EDITION.

IN the Spring of 1893 I gave a lecture in the West Riding of Yorkshire, under the auspices of the Sanitary Institute and other bodies, upon the "Drainage of Villages and Isolated Houses," which was afterwards printed and published, and it appears to have been of some service, as for some time past the issue has been exhausted, and it has been thought desirable to offer a new one on a more extended plan, and presenting more complete information than is possible in the delivery of an oral lecture. I have also added an entirely new portion in Part I. dealing with the statutory powers and obligations. There is so much of what is needed scattered throughout at least four Acts of Parliament, that I hope it will be found an advantage to have the substance of the sections collected in a short compass and in direct sequence. Part II. comprises the points which have to be considered in the preparation of a scheme, and this has been considerably revised and enlarged also. Part III. relates to engineering matters concerned with the construction of sewers. This remains much as it was in the first edition, in which it will be seen that at the delivery of the lecture I made frequent sketches of the details referred to upon the black board. No doubt it would have been a great advantage to have had this part copiously illustrated with plans, sections, and detail drawings; but this is not a text book for students, nor an "Inquire within upon Everything"

for Sanitary Engineers, it is only a revise, as I have stated, of a reprint of a lecture of one hour's duration. Perhaps even in this part some of the information will be beneficial, and to those who have not access to Baldwin Latham's "Sanitary Engineering," I would commend Savage's "Sewering of a Small Town" (London, Biggs and Co.), which is illustrated with all the necessary drawings. For full instructions as to the preparation of plans and sections required by the Local Government Board in connection with the application for sanctions to loans, the "Suggestions" of Sir Robt. Rawlinson, which are published by Knight and Co., should be consulted. Appendix A. of that work also contains full information as to contracts and specifications, and Appendix B. instructions as to applications for Provisional orders to put in force the Compulsory Powers of the Land Clauses Consolidations Acts, but as these are subject to variation in accordance with the Standing Orders of the Houses of Parliament, application for printed copies of the instructions issued should be made when required to the Local Government Board. Part IV., treating of "Sewage Disposal," I have also extended somewhat, as even in the past two years there have been changes, if not improvements, and at any rate developments. Here again I am only able to direct attention to main features, and for exhaustive detail must refer to such works as Santo Crimp's "Sewage Disposal."

The subject of Isolated Dwellings I have eliminated from this edition, as I hope shortly to take that up in another

work which I have in preparation. I have retained the tables and interpolated some additional ones ; it is useful to have these at hand under one cover, instead of having to search for them over various shelves.

I am conscious of many shortcomings and errors, but must plead the well-worn excuse of want of proper time; certainly that which is available at the close of busy days is not the most suitable for the compiling and arranging of the necessary matter. Such as it is, I trust the work may be of help to those engaged in the conception, maturing, and development of Village Drainage.

PRUDENTIAL ASSURANCE BUILDINGS, LEEDS.
November, 1895.

SYNOPSIS OF CONTENTS.

THE DRAINAGE OF VILLAGES.

INTRODUCTORY.

THE formation of Parish Councils throughout the country has caused a more direct interest to be taken in sanitary matters by the inhabitants of villages, and, generally speaking, more active measures are being taken by Rural District Councils, possibly owing to increased pressure being put upon them by the County Councils and by the Rivers Boards formed under the powers of the County Government Act, 1888, so that in every direction steps are being taken in the preparation of schemes of drainage for villages. The period of contemplation and *laissez faire* admittedly is past, and under the new *régime* something has to be done, and it is the various stages of that something that I propose to trace, in the hope that it will not only be a guide to parochial rulers, but also of some assistance to their officials and advisers, and to facilitate the perusal of these pages, I have added in Table 1 an interpretation of the technical terms used, words which are in practice so commonly misapplied, none perhaps more so than sewage and sewerage.

The many points that have to be observed in the preparation of a scheme of town sewerage apply equally to villages, with the exception that there are not so many engineering difficulties to be grappled with. Before proceeding to illustrate these points it would be as well, in the first place, just

to consider the statutory powers regulating sewerage and sewage disposal.

Parish Councils have no direct concern with sewerage matters, such being under the control of the District Council; indirectly they are concerned by having the power of complaint in the manner hereafter referred to, and by Section 16 (3) of the Local Government Act, 1894, they are entitled to notice from the District Council when the latter have determined to adopt plans for sewerage, and before the District Council have entered into any contract for the execution of the work.

PART I.

STATUTORY POWERS.

Part III. of the Public Health Act, 1875, contains the regulations as to sewers and drains, which are defined in Section 4 as follows:—"*Drain*" means "any drain of, and used for the drainage of one building only, or premises within the same curtilage, and made merely for the purpose of communicating therefrom with a cesspool or other like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed."

"*Sewer*" includes "sewers and drains of every description except drains to which the word "*drain*," interpreted as aforesaid, applies, and except drains vested in or under the control of any authority having the management of roads, and not being a local authority under this Act.

COMBINED DRAINAGE.

The definition of drain as here set forth is most important, because by the decision in *"Travis *v.* Uttley," it has been held that no matter where a drain is laid, if it is on private property, and even passing under houses, so long as it receives the drainage of two or more buildings within the same curtilage it is in law a sewer, and under Section 13 of the Act, is vested in and is under the control of the Local Authority.† Section 15 states: "Every Local Authority shall keep in repair all sewers belonging to them, and shall cause to be made such sewers as may be necessary for effectually draining their district for the purposes of this Act;" and under Section 18 they have also power to alter or discontinue sewers, provided that the doing so does not result in a nuisance being created; and further, by Section 19, it is obligatory upon them to cause all sewers belonging to them to be constructed, covered, and ventilated so as not to be a nuisance or injurious to health, and to be properly cleansed and emptied; and under Section 27 they may, "for the purpose of receiving, storing, disinfecting, distributing, or otherwise disposing of sewage—

* Travis *v.* Uttley, Court of Appeal, November 27th, December 4th, 1893—L. R., 1894: I. Q. B. D., page 233. Drain passing under three houses and discharging sewage from all three into public sewer. Held to be a sewer under Section 4 of the Public Health Act, 1875.

† In a later case, Self *v.* Hove Commissioners (Q B. D., 25th Jan., 1895), the Council having adopted Part III. of the Public Health Amendment Act, 1890, the Court held that the case came within the meaning of drain as interpreted in Section 19 of that Act, and was not a sewer; but the same Court on 3rd April, 1895, in case of Hill *v.* Hair, held that this Section would only apply to drains laid since the passing of that Act (1890).

"(1) Construct any works within their district, or—subject to the provision of the Act as to sewage works without the district of the Local Authority—without their district; and

"(2) Contract for the use of, purchase, or take on lease, any land, buildings, engines, materials, or appliances, either within or without their district."

The other sections deal with regulations to be observed in the maintenance of sewers and the connection of house drains, &c., and I shall only refer to such as are necessary for the present purpose.

POLLUTION OF STREAMS.

While Local Authorities have the power to construct sewers, they are prohibited from allowing the sewage matter flowing through the sewers to discharge into any stream. Section 3 of the Rivers Pollution Prevention Act, 1876, states, "Every person who causes to fall or flow or knowingly permits to fall or flow or to be carried into any stream any solid or liquid sewage matter shall, subject as in this Act mentioned, be deemed to have committed an offence against this Act." And then follows the procedure, penalties, &c. In 1893 this section was repealed, and a short Act was passed (56 and 57 Vict., Chap. 31), wherein the section is made to read thus :—"Where any sewage matter falls or flows or is carried into any stream after passing through or along a channel which is vested in a Sanitary Authority, the Sanitary Authority shall, for the purposes of Section 3 of the Rivers Pollution Prevention Act, 1876, be deemed to knowingly permit the sewage matter so to fall, flow, or be carried." Section 7 regulates the use of sewers by manufacturers for trade effluents.

By Section 20 stream is thus defined:—"Stream includes the sea to such extent and tidal waters to such point as may, after local inquiry and on sanitary grounds, be determined by the Local Government Board, by order published in the *London Gazette.* Save as aforesaid, it includes rivers, streams, canals, lakes, and watercourses other than watercourses at the passing of this Act, mainly used as sewers and emptying direct into the sea, or tidal waters which have not been determined to be streams within the meaning of this Act, by such order as aforesaid."

In the watershed areas of the Mersey and Irwell and of the West Riding of Yorkshire, where offences are committed by Local Authorities against the provisions of the Special Acts in force in those areas, the joint committees are empowered to fix a prescribed time in which curative works are to be executed, and failing this legal proceedings can be taken and penalties imposed and an order issued imposing conditions subject to an appeal to Quarter Sessions.

Under the Rivers Pollution Prevention Act the Local Government Board in the first instance, and afterwards the County Court, are the authorities to deal with offences of pollution, but the restrictions contained in the Act are such as to preclude effective action for the improvement of the condition of the streams.

IN CASE OF FAILURE TO PROVIDE SEWERAGE SCHEMES.

It is clear, therefore, that Local Authorities not only have ample powers to construct sewers and carry out sewage disposal works, but in so doing they must not cause pollutions of streams, and that the obligation is upon them to

take the initiative without any pressure from the outside; if they fail to provide sufficient sewers for their district, or in the maintenance of existing sewers, complaint can be made under the powers conferred by Section 299 of the Public Health Act, 1875, to the Local Government Board, who, if satisfied after due inquiry that the authority is guilty of the alleged default, can make an order limiting the time for carrying out the necessary works, and if the duty imposed is not carried out within the time specified, the order may be enforced by a Writ of Mandamus, or the Local Government Board may appoint some person to perform the duty, and all costs incurred shall be a charge upon the rates.

Or the Parish Council may complain to the County Council (in the manner prescribed in the Local Government Act, 1894, Sec. 16 (1) of the default of the Rural District Council, and the County Council, if after due inquiry, are satisfied that the District Council have failed as respects the subject matter of complaint, may resolve that the duties and powers of the District Council for the purpose of the matter complained of, shall be transferred to the County Council, or they may appoint some person to perform the duty, making such an order as is referred to in Sec. 299 of the Public Health Act, 1875.

EXISTING SEWERS.

Before the lines of any new system are decided upon, a careful examination of all existing sewers should be made to see if they are or can be made into a fit condition for incorporation in a complete and efficient scheme. As a general rule, the sewers met with are either constructed of rubble or bricks laid dry, and sometimes of egg-shaped earthen-

ware pipes. They are often irregular in line, very shallow, having been primarily put down to carry off surface water only, and nearly always contain a deposit of several inches of sewage sludge and slime, which is extremely foul and dangerous to health. Owing to the methods of construction and the want of ready access, it is impossible to cleanse these sewers, and the roughness and irregularity of their interiors tend to arrest the flow of the sewage along them, and to cause deposit of the solid matter in suspension, and the open joints allow of constant leakage and serious pollution of the subsoil. For these reasons, and bearing in mind that in the future, and at no distant date either, water carriage systems will be universally adopted, it is abundantly clear that such sewers are not adapted for the conveyance of domestic sewage, and it is idle to go before the Local Government Board with any scheme which includes their maintenance for such a purpose ; but they need not be altogether abandoned, as they can be put to do useful service in a harmless way, as I shall hereafter show.

PRESENT MEANS OF DISPOSAL.

In some villages the sewage is not poured directly into streams, but is turned over land, but in such a way as to effect little or no purification, owing to the lack of the proper knowledge, defects in the application, and want of regular and systematic attention, the consequence of which is that it flows for long-continued periods on to one particular spot, the ground becomes surcharged with offensive matter, and the sewage finds its way in a highly turbid state into the stream ; or, again, the area of land selected is either too small for the purpose, or the soil is altogether unsuitable

for this method of treatment. Another method is to pour the sewage into cesspools or sumps, which are generally contrived to have an overflow. In these cases there is a deposit of sludge which is rarely removed, at any rate not until the condition of things is intolerable, and the sewage passes on in a much worse state by the overflow to the stream. Both of these methods are only makeshifts; they are certainly economical from a £ s. d. point of view, and are only an evasion of the conditions imposed by the Acts of Parliament. The simpler methods of pouring the sewage direct into a stream, canal, or reservoir, is more honest, and all alike are culpable. It is felt by many, some of whom are not solely inhabitants of villages, that sewage that does not contain excrementitious matter cannot cause pollution. Let us for a moment examine this contention.

COMPOSITION OF SEWAGE.

In the first place, what is sewage? and apart from human excrement, it contains urine, nearly the whole of which finds its way into the sewers through the chamber slops. There is sink water from wash-houses and kitchens, the drainage from stables and cowhouses, and slaughter-houses; the washing-up water from floors and walls, and the swilling out of cellars and of publichouse stillages, the water used in personal ablution, all of which, when combined, makes a highly complex liquid, and is extremely strong in polluting agents. This question was raised before the Rivers Pollution Commission in 1868, and they caused several samples of sewage from dry-closeted towns, and water-closeted towns to be analysed, and the results are shown in the Table on next page:—

One would have thought that the publication of these

results would have effectually laid this ghost, but he possesses wonderful recuperative powers, and is still perambulating the land doling out little bits of cold comfort here and there, and it is now quite time that he dissembled for good and all.

AVERAGE COMPOSITION OF SEWAGE.

In Parts per 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended matters		
							Mineral.	Organic.	Total.
Midden Towns	82·4	4·181	1·975	5 435	6·451	11·54	17·81	21·30	39·11
W. C. Towns	72·2	4·696	2·205	6·703	7·728	10·66	24·18	20·51	44·69
In Grains per Gallon.									
Midden Towns	57·68	2·926	1·382	3·804	4·515	8·078	12·467	14·910	27 377
W. C. Towns	50·54	3·287	1·543	4·692	5 410	7·462	16·926	14·357	31 283

In the West Riding of Yorkshire Rivers Act, 1894, Section 3, the following definition is given to the word: "Sewage" includes unpurified urine, excrementitious matter, and liquid refuse of any house or premises, blood and the washing of a slaughter-house containing blood or urinary or fœcal matter, but shall not include any liquid rendered poisonous, noxious, or polluting in the course of some manufacturing process."

SELF-PURIFYING POWER OF STREAMS.

Another piece of comfort that these advocates possess is that, because after travelling a short distance along a stream,

and commingling with its waters, the sewage loses its turbidity, and the discoloration ceases, there is therefore no pollution.

This process of change is entirely dependent upon the volume of water in the stream, and the relation it bears to the quantity of sewage poured in at all times and seasons, and in the present state of our knowledge as to self-purifying power of rivers, this contention cannot with safety be acceded to.

The subject has been extensively discussed of late years, notably by Dr. Frankland, at the International Congress of Hygiene, held in London in 1891,* and again by Mr. H. A. Roechling, A.M.I.C.E., at the Annual Meeting of the Incorporated Association of Municipal and County Engineers, held at Bury in 1891.†

Dr. Frankland is of opinion that "sedimentation is the main cause of any self-purification in river water. Of any rapid oxidation of dissolved organic matter there is still no reliable evidence, although of course dilution which frequently takes place on the larger scale, as in the case of the Thames, without being suspected until made the subject of a most careful scrutiny, will produce a superficial appearance of such a result."

Mr. Roechling lays great stress on the investigations by Pettenkofer on the river Isar at Munich, where the velocity is 4ft. per second and the discharge 1400 cubic feet, the raw sewage amounts to 40 cubic feet or 2·5 per cent., and Pettenkofer is sanguine that in this case no pollution will

* "Transactions" of the Seventh International Congress of Hygiene and Demography, Vol. vii., p. 70.

† "Proceedings" of the Incorporated Association of Municipal and County Engineers, Vol. xviii., p. 336.

ensue, and he is also of opinion that if the sewage never amounts to more than $\frac{1}{15}$, or 6·7 per cent. of the river water, and the velocity of the latter is at least equal to that of the former, the raw sewage may be poured into such river without causing pollution. In America Mr. J. P. Stearns, the Engineer to the Massachusetts State Board of Health, has also investigated the same questions, and his conclusions are that if the sewage amounts to more than $\frac{1}{40}$, or 2·5 per cent. of the quantity of river water, it cannot be discharged into the river in its raw state; if it amounts to less than $\frac{1}{40}$, or 2·5 per cent., and more than $\frac{1}{130}$, or 0·8 per cent., it is doubtful whether it may be admitted; but when the sewage amounts to less than $\frac{1}{130}$, or 0·8 per cent. of the river water, then, without any doubt, it may be admitted in its raw state into the river. Stearns adds that these considerations are made from the "standpoint of the offensiveness of the water." These conclusions have not yet been accepted as final by English authorities, so there is no relaxation in the administering of the Rivers Pollution Prevention Act, and especially should this be the case where river water is abstracted for dietetic purposes. The condition of things in the Tees Valley in 1890-91, as disclosed by the report of Dr. Barry to the Local Government Board, issued August, 1893,* seems hardly credible, so filthy was the state of the river about Barnard Castle and above the intakes of the Waterworks. At the particular times referred to in the report there were two very serious outbreaks of enteric fever amongst a population of 500,000 persons; there was nothing in the general sanitary conditions of the

* Twentieth Annual Report of the Local Government Board, 1891-2, Supplement.

urban or rural districts to account for such abnormal outbreaks, but when the water supply was investigated, it was found that not only the sewage but a great proportion of solid filth, from 10,000 persons, was poured directly into the river without any pretence at concealment, and in times of flood this was carried down to and past the intakes of the waterworks, and while the epidemic lasted the death-rate from enteric fever per 10,000 of the population was, amongst users of the Tees water 10·3, and for non-users 2·1.

PART II.

AREAS OF THE DISTRICT TO BE SEWERED.

The first consideration in any scheme of sewerage is the area intended to be dealt with. This should be clearly shown upon the 6in. ordnance map, the boundary of the parish being distinctly coloured as well as the boundaries of the several adjoining parishes, and where the parish is situate on the borders of the rural district area, then the boundaries of the adjoining rural district areas should also be clearly shown by distinguishing colours. Many parishes contain within their areas, besides the particular village from which they take their name, detached groups of houses, some of them of considerable extent, and this is especially the case in colliery and manufacturing districts. These will most likely form separate drainage areas, and should also be coloured distinctively. On the 6in. ordnance maps the contour levels of every 25ft. of altitude are shown in fine dotted lines, and it is as well also to trace these out and colour each of them with a distinguishing colour, writing on in bold figures their respective levels. The boundaries, areas, and

contours being thus distinctively marked, the comprehension of the map is rendered much more simple, and will be found of great assistance in making an examination of the ground, as it will be easy to see at a glance the precise level of one particular spot, and its relation to other adjoining places.

The designing of a system of sewerage depends for its ultimate success in the selection of such routes for the collecting sewers, known as intercepting sewers, as will afford the largest amount of duty at the least expense in the cost of construction and easements, and it is in the performance of this work that the value of an ordnance map, prepared as above described, is appreciated, and one may say of such importance. In choosing these lines, the levels are of course the first consideration, next the direction, which must be so chosen as to be contiguous to all the property from which the sewage has to be collected. As far as possible the lines of roads should be followed, but in valleys—especially where the backs of the houses are at a lower level than the road in front, and where the surface of the ground slopes away from it—it is nearly always necessary to run the intercepting sewer at such a level as will necessitate the taking of it through private land.

POWER TO ENTER PRIVATE LANDS.

The Local Authority has very large powers of entry on lands under Sec. 16 of the Public Health Act, 1875, "to carry any sewer through, across, or under any turnpike road or any street, or place laid out as or intended for a street, or under any cellar or vault which may be under the pavement or carriage-way of any street, and, after giving reasonable notice in writing to the owner or occupier (if, on the report of the surveyor, it appears

necessary), into, through, or under any lands whatsoever within their district. They may also (subject to the provisions of this Act relating to sewage works without the district of the Local Authority) exercise all or any of the powers given by this section without their district for the purpose of outfall or distribution of sewage." Section 308 sets forth that any person who sustains damage shall be compensated, and Section 179 provides the machinery for settling that compensation in case of failure to agree between the parties, and in addition to the surface damage paid to the tenant, there is the damage to the estate by reason of the occupation of the freehold by the sewer and the easement for the right of way to repair to be settled for. For further and fuller details upon this question reference should be made to the very excellent paper by Mr. Robert Godfrey, A.M.I.C.E., published in the Transactions of the Association of Municipal and County Engineers.* Again, to keep down the extent of the easements, and to minimise the nature of the damage likely to arise, great care must be taken in the selection of these lines.

WORKS WITHOUT DISTRICT.

It is sometimes necessary to carry the sewer through portions of an adjoining parish, and especially where the collecting of the sewage from outlying districts has to be accomplished, and in this case also the Local Authority has very full powers conferred upon them by Section 32 of the Public Health Act, 1875, and they shall, "Three months at least before commencing the construction or extension of any sewer or other work for

* See vol. xvii. p. 176 ; E. and F. N. Spon, London ; price 12s. 6d.

sewage purposes without their district, give notice of the intended work by advertisement in one or more of the local newspapers circulated within the district where the work is to be made. Such notice shall describe the nature of the intended work, and shall state the intended termini thereof, and the names of the parishes, and the turnpike roads and streets, and other lands (if any) through, across, under, or on which the work is to be made, and shall name a place where a plan of the intended work is open for inspection at all reasonable hours; and a copy of such notice shall be served on the owners or reputed owners, lessees or reputed lessees, and occupiers of the said lands, and on the overseers of such parishes, and on the trustees, surveyors of highways, or other persons having the care of such roads or streets." In case of objection, the works are not to be commenced without the sanction of the Local Government Board (see Section 33), who may, on the application of the Local Authority, hold an inquiry by an inspector on the spot into the propriety of the intended work and the objections thereto, and on his report the Local Government Board may make whatever orders they deem necessary (see Section 34).

SPECIAL DRAINAGE DISTRICTS.

Where there are a number of separate drainage areas in a parish it is as well to consider if it would be more economical to have distinct schemes for each. By Section 277 of the Public Health Act, 1875, separate contributory places may be set up subject to the order of the Local Government Board.* Oftentimes there is great difficulty in

* For instructions of the Local Government Board, see addendum, page 47.

agreeing as to the boundaries of these contributory districts, and it is perhaps as well to keep to the township boundaries even at the risk of inflicting a hardship upon some rate-payers who, from the physical difficulties surrounding their premises, may derive no benefit from the contemplated works.

POWER TO AGREE WITH NEIGHBOURING AUTHORITY TO TAKE AND DEAL WITH SEWAGE.

Local Authorities may sometimes find it to their advantage to have their sewage connected to the system in an adjoining district, and Section 28 of the Public Health Act, 1875, gives them power to make agreements for this purpose, subject to the approval of the Local Government Board, who in cases of dispute may settle the terms and conditions. It is provided that no storm water is to be passed into the sewers, and that the Authority delivering the sewage shall not pass through their sewers any sewage from other districts without the consent of the Authority which is taking the sewage for disposal.

JOINT SEWERAGE BOARDS.

Many parishes are so situated in valleys—that is on both sides of or are contiguous to one another in converging valleys, that possibly if each were to carry out separate sewage schemes there would be half a dozen sets of disposal works dotted up and down within a distance of a mile or so. In cases like these, where it is feasible to do so, it is a distinct advantage to group these districts for drainage purposes, and form a Joint Sewerage Board, under the powers conferred in that behalf by Section 279 of the Public Health Act, 1875. Application must first be made to the

Local Government Board, who may, by Provisional Order, form a united district out of the contributory places. Sections 280 to 284 deal with the details of the formation, duties and powers of such Joint Boards.

RAINFALL.

Having examined the area to be sewered and decided upon its boundaries, the next point to consider is the rainfall and the proportion it is intended to take into the sewers.

A district may have two systems of sewers, one to carry off the rainwater solely, and the other the sewage; but it is obvious that to have two sets of drains upon the back premises of houses would require constant overlooking, and that sooner or later they would become disorganised. The Local Government Board very properly advise that as little rainfall as possible should be taken into the sewers; certainly all that falls on the back part of the roofs and the back yards and passages will find its way into the house drains and must be taken in; that which falls upon the front part of the roofs and the surfaces of the roads may be conveyed away by the old drains after they have been put into proper order. The quantity of rain for which provision must be made in rural parishes should be a quarter of an inch per day. In Table No. 2 will be found the quantities of rainfall per acre in gallons and cubic feet at varying depths up to 1in., and in Table No. 3 will be found the quantity which is discharged from various surfaces which are met with about houses after evaporation and absorption. We occasionally have excessive rainstorms, although on the average there are only six days in the year when more than half an inch of rain falls, and provision must be made at suitable points for passing this storm

water by means of overflows into streams or dykes. No fixed rule can be laid down for the proportion this storm water shall bear to the sewage, as that will depend upon the impurity of the sewage and the standard of purity which must be attained before it will be allowed by the River Conservancy Authorities to be turned into the rivers. In some villages sewage is so weak that if it is diluted with three or four times its bulk by rainwater it would be safe so to pass it, and in other cases it would require dilution by as much as eight or ten times its bulk by rainwater.

THE GEOLOGICAL CHARACTER OF THE DISTRICT.

The geological character of the district may be ascertained generally from the sheets published by the Ordnance Survey Department, but as it is only in exceptional cases where the rock crops up so near to the surface as to be liable to be cut into by the sewer trench, it is advisable to seek on the spot for more precise information as to the strata overlying the rock. Indications of what is likely to be met with may be found in railway cuttings and the excavations for cellars, and the knowledge and experience of the local well sinker should be sought, so that as far as possible all those features which add to the difficulties and expense of sewerage works may be ascertained. In colliery districts a comparison should be made of the contour levels and bench marks shown upon the recent issues of the Ordnance sheets with those shown upon the maps of the 1848 Survey, to see in what direction and to what extent settling has taken place, and for future guidance it should be ascertained what seams remain unworked and the extent of settling that is likely to ensue after the coal is won. The boundaries of shaft pillars should be carefully noted, as well as those of

other supports that may have been left. Attention may very properly be called here to the Public Health Act, 1875 (Support of Sewers) Amendment Act, 1883—46 and 47 Vict., Chapter 37, which is an Act to amend the Public Health Act and to make provision with respect to the support of public sewers and sewerage works in mining districts. It is important also to ascertain whether there is any prevalence of quicksand in the district, and the nature and extent of it, and also if there are any water-bearing strata, such as gravel, overlying impervious formations, as great costs have to be incurred in dealing with streams of water which are often to be found running through these beds, either by making provision for its permanent passage or by temporary works and pumping during the progress of the sewerage operations.

PRESENT AND PROSPECTIVE NUMBER OF INHABITANTS.

Before it is possible to ascertain the amount of sewage due to the population, the number of inhabitants within the area of the scheme must be learnt. In the first place, we turn to the returns of the last census, from which we can find the number of houses and the then population, and a simple division sum will record the number of inhabitants per house. Next count the number of occupied houses and multiply by the figure of inhabitants per house, and you have the present population. For future increase it is as well to refer to the census returns for the past thirty years, and note the proportionate increase at each decennial period, and calculate upon that basis for the next thirty years. I am afraid that in purely agricultural districts this will present no difficulties, and that the researches will reveal that the population has, like the cow's tail, been growing

downwards. In manufacturing, and especially colliery districts, on the other hand, it is impossible to forecast the prospective number of inhabitants. In the last few years sleepy rural hamlets in the South Yorkshire coal fields have been transformed into busy little towns in a very short space of time, with every indications of long-continued prosperity, and the cry is still they come, and so it will be as long as there are mineral resources awaiting development.

THE SUPPLY OF WATER.

Having ascertained the number of inhabitants, the next point to determine is the amount of sewage which is likely to be created by them, and which has to be conveyed away, and which is of course the water which has been used in the house for dietetic, domestic, and cleansing purposes. Dr. Parkes has stated that he found 12 gallons per head per day to be the quantity used by a healthy man in a clean household, made up as follows :—

Cooking...	·75	gallons
Fluids (as drink, water, tea, coffee) ...	·33	,,
Ablution, including daily sponge bath, taking $2\frac{1}{2}$ to 3 gallons...	5·00	,,
Share of Utensil and House washing	3·00	,,
Share of clothes (laundry) washing ...	3·00	,,
	12·08	gallons

But in rural districts this will be found a rather high amount per head where there is no regular supply laid on to each house, and where the water has to be carried from wells or stand pipes the amount does not exceed in cottages seven gallons per head per day, and even when the water is laid on the quantity so used is not more than 10 gallons per head. On the other hand, in houses where they have sani-

tary conveniences well arranged, and baths are taken frequently, the consumption may be anything from 40 to 70 gallons per head per day. If water-closets are to be used, then in addition to the figure of 10 gallons above mentioned 5 gallons must be allowed for the purpose if the closets are to be flushed from the public supply, but if slop water-closets are adopted then no increase need be provided. The actual amount of water supplied to a district does not necessarily become sewage, as there are deductions to be made for water used for public purposes, such as road watering, extinguishing of fires, flushing mains, and the loss due to leakages.

SANITARY APPLIANCES.

The sanitary appliances must next be inspected, to ascertain what system is in general use, whether it be the midden, pail, or water carriage, and also the general condition of the closets, and the methods of scavenging should be noted. A great deal of the insanitary condition of our villages is due to the wretched character of these arrangements, and there is no doubt if the people did not live so much in the open air they would be carried off by some pestilential outbreak. The midden system is an abominably filthy and insanitary one, and should be exterminated, so the continuance of it must not be taken into calculation. The pail system is a palliation, and if properly attended to by the sanitary authority, it may be tolerated. Water carriage in some form is the only sanitary system, and the sewers and drains should be so constructed and ventilated as to be fitted for it, and on the whole the slop water system is best adapted for cottage property, owing to its being automatic in its action and its non-liability to freeze in winter;

and in this view I am supported by such well-known authorities as Dr. Sergeant, the County Medical Officer of Lancashire, and Mr. Taylor, the Borough and Water Engineer of Barnsley, who has made the most careful investigations into this system. It is a popular idea that the sizes of drains are affected by the amount of extra sewage which would have to be conveyed from water-closets. This is a convenient delusion, the amount is so trifling as to make no appreciable difference in the depth of flow in the sewer; but what is of the utmost consequence is that the sewers should be absolutely water-tight, laid true to line and gradient, and properly ventilated and flushed.

POSITION OF OUTFALL WORKS.

The last point to be considered in the preparation of a scheme of sewerage is the position of the outfall works. In selecting this, regard must always be had to the holy horror of the imaginary smells which are alleged to be given off from such places. It is well known that a well laid out and intelligently managed sewage works need create no nuisance, but in spite of assurances to that effect, there is the sentimental objection and the cry of depreciation of property to be met; therefore the site should not be nearer in a direct line, no matter in what direction, than 200 yards to any dwelling, whether within or without the district. The land so selected should be convenient of access by cart, and the surface should be of suitable level, and there should be at least available a fall of 10ft. from the surface at the inlet to the site to the normal level of the stream at the point where the effluent water will be discharged, and attention must also be given to the indications of flood levels. The nature of the soil must also be carefully noted,

as well as the character of the subsoil, say to a depth of 6ft. or 7ft.

POWER TO PURCHASE LANDS.

Local Authorities are endowed with ample powers to purchase lands. By Section 175 of the Public Health Act, 1875, they may "for the purposes, and subject to the provisions of this Act, purchase or take on lease, sell, or exchange, any lands, whether within or without their district."

With regard to the leasing of land, it should be explained that the Local Government Board will only sanction loans for works proposed to be constructed on leasehold land for the period of time for which the land is leased, but not exceeding forty years, so endeavours should always be made to obtain leases at least for that length of time. Sites possessing most excellent features are not always easily acquired, on account of the unwillingness of the owner to sell, or of prohibitive prices being asked. Land for this purpose is worth more than merely agricultural land, and it is now well established that if a specific site is adapted by its position and other characteristics for public uses, that the owner is entitled to such a value as it would have and would represent to the Local Authority, but it is not intended that it is to be paid for as building land, unless its situation should warrant it. In case of an unwillingness to sell land, the Local Authority have power to avail themselves of the Lands Clauses Consolidation Acts, and the regulations as to purchase of land will be found in detail in Section 176 of the Public Health Act, 1875, the procedure being first to obtain a Provisional Order from the Local Government Board, which has to be confirmed by

Parliament in the usual way, before it becomes operative (see Sections 297-8). The costs of doing this, and also the extra costs incurred in purchasing land compulsorily, even without resorting to arbitration, add a great deal to the value of the land, and it is advisable for the Local Authority first to consider exhaustively every possible alternative, even inclusive of pumping, or similar costs, before finally deciding to avail themselves of these powers.

It will be noted that sewage disposal works may be taken into another district, but this should only be done under very exceptional circumstances, such as the difficulty of obtaining suitable land at the requisite levels within the district. For instance, there are cases where parishes are built upon right up to the boundary, or, again, there are narrow valleys where an adequate area of land cannot possibly be acquired within the district. It must also be remembered that these works are subject to assessment and rating when situated in an adjoining district. When an owner is willing to sell upon terms agreed upon, a provisional contract to purchase should be entered into, the purchase to be conditional upon the scheme receiving the approval of the Local Government Board, and it should include all stipulations as to roads, fences, &c., and should be produced at the Local Government Board inquiry for review by the Inspector if he desires it.

BORROWING POWERS.

By Section 233 of the Public Health Act the Local Authority are empowered to borrow money on credit of the rates, and Section 234 contains the regulations as to exercise

of borrowing powers. Sub-section 2 states that "the sum borrowed shall not at any time exceed, with the balance of all the outstanding loans contracted by the Local Authority under the Sanitary Acts and this Act, in the whole the assessable value for two years of the premises assessable within the district in respect of which such money may be borrowed."

It is important that this condition should be carefully borne in mind. Under Section 244 joint sewerage boards possess the same powers as to borrowing, and are subject to the same restrictions as are conferred upon Local Authorities.

PART III.

REQUIREMENTS OF A SEWERAGE SYSTEM.

The "Hints and Suggestions" issued in 1878 by Sir Robert Rawlinson, when he was Chief Engineering Inspector to the Local Government Board, contain all the requirements which a good sewerage system should embrace, and they have been very succinctly defined by Mr. H. P. Boulnois, M.I.C.E., City Engineer of Liverpool, in his "Municipal and Sanitary Engineers' Handbook,"* pages 290 and 291, and the simplest plan will perhaps be to follow the order there given :—

DEPTHS.

(1) Each sewer should be laid at such a depth as will readily drain the basement of the adjoining buildings.

The levels of all basements should be carefully recorded on the sections, and provision should be made for future

* E. and F. N. Spon, London, price 15s.

cellars upon land that is at present unbuilt upon, and proper allowance made for the requisite fall in the cellar drain from the house to the sewer; a depth of 12ft. will be found sufficient for cellar drainage, though it need not always be as deep as that. I must not here be understood as advocating cellar drainage; on the contrary, I am entirely opposed to it, as no cellars except public house stillages and wash cellars require gullies; these should always be placed outside in an area, so as to avoid having any communication from the interior of the house to the main sewer. Attention should also be paid to the levels of drains at the backs of houses where the road is across the slope of a hill, and the course and levels of all brooks and their coverings recorded.

GRADIENTS.

(2) Its area and gradient must be so regulated as to make it self-cleansing, and at the same time carry off effectively the maximum quantity of liquid for which it is intended. I have already pointed out the duties which sewers are called upon to perform, and in calculating the amount to be discharged, care must be taken to double the quantity which is due to the domestic sewage during the active portion of the day, and to this must be added the rainfall. It is usual to allow a mean velocity of 2ft. per second to keep a sewer self-cleansing. Bottom velocity, which imparts the greatest motion, differs from mean velocity in the ratio of from ·75 to ·85 — say ·80 to 1, or four-fifths. The greatest discharge from a circular pipe is when it is not quite full—that is, when rather better than fifteen-sixteenths full—and the greater velocity occurs when it is thirteen-sixteenths full. The exact actual discharge of

a sewer at any point is very difficult to calculate, owing to the numerous branches and connections and the volumes of sewage and rain-water they are pouring in; in this respect a sewer is the exact reverse of a water main, as in that case the volume diminishes the more the pipe is prolonged from the intake. It is usual in this country to calculate the discharge of a sewer from Beardmore's well-known formula (see Table No. 4), In Table No. 5 will be found some very useful calculations in working out the discharges of small sewers at varying depths of flow.

Excessively steep gradients are to be avoided, as they tend to the destruction of earthenware pipe sewers, so that it is frequently advisable to make drops in manholes. In cases where it would be costly to do this, such as in excavating rock, then iron pipes should be used in preference to stoneware.

LINES.

(3) Each sewer should (unless quite impracticable) be laid in straight lines and with even gradients between manholes. The advantage of this method must be obvious, by having a manhole for inspection at every change of direction and gradient, it is possible to examine the sewer at any time, and the position of the sewer at any intermediate point can be found accurately, the importance of this when new junctions are required is clear. In fact, it is only by following this system that the whole of the sewers are fully under inspection and command. All turning must be done in the channels of the manholes, and the branch sewers coming in should deliver into the manhole at a level above the dry weather flow in the main sewer, and the branch channels be curved in the direction of its flow. This method

will not impede flow in the main, and will prevent the tributary sewers being backwatered and the deposit of silt which it causes in the submerged invert.

SEWERS AND THEIR JOINTING.

In villages, sewers of circular socketted glazed earthenware or stoneware pipes will make the best conduits, the joints in all cases being made of tarred gasket and cement, none but the best quality of pipes being used, as it is essential that all sewers must be water-tight, and the better the material and workmanship the more excellent the sewer, there being less liability to stoppage, and a higher discharging capacity. For really first-class work there is nothing better than the Hassall single-lined pipe; it saves the necessity of caulking the joint, and removes all doubts as to scamping in the temporary absence of oversight, and there is no trouble about "seconds" or imperfect pipes. They do not require centreing, as they are perfectly cylindrical, and consequently take less time to lay and less cement to complete the joint. The first cost of the pipe is slightly more than an ordinary pipe, but after making deductions for the cost of jointing, the excess per yard on such small sizes as are required for village drainage is not worth considering when such high-class work has been accomplished. In sinking ground this pipe should always be used with the joints completed in plastic cement. As this never sets hard, the pipes can be disconnected without damage and the sewer relaid whenever required, and it is sufficiently yielding as to prevent the cracking which would follow the settling in case a rigid joint was used. Where the ground is waterlogged, or where the sewer has to be laid alongside a watercourse, then the very best possible joint for the pur-

pose is the Hassall double-lined safety pipe, which when completed in the trench has three joints. One great advantage of this pipe is that it can be rapidly laid and jointed even in water. A firm foundation should always be provided for the pipes, concrete being used whenever necessary.

When sewers are out of ground the foundation should either be of concrete or a firmly laid dry stone wall, and an embankment properly covering the pipe; where leaps or gullies have to be crossed, then the sewers must be of iron supported on piers. Where railways and canals are to be passed under, iron pipes must also be used surrounded with concrete, and if the work is in tunnel, then the heading must be close packed with dry stone scapplings. When the road is carried over the railway the sewer must be swung to one side, so as to clear the piers and wing walls, and when the railway crosses the road the depth of footings of the piers must be ascertained, and the trench refilled over the sewer with concrete to that level, so as to prevent the piers being drawn by any "shunting" of the ground between them and the sewer. Brooks and streams may have to be passed under at times, owing to the levels, by a syphon, and these pipes should always be in duplicate, with valves at either end to divert the sewage into one or the other in case of stoppage; there should also be a well on both sides of the stream for inspection and cleansing purposes.

MANHOLES.

The manholes should be of simple construction, large enough for two men to work in them, say, 6ft. long, by 2ft. 3in. wide in the chamber. The foundations should be con-

crete, the channel being inverted and formed of salt glazed radiated bricks. Where the sewer is over 7ft. in depth, the chamber will require arching over and a shaft carrying to the surface about 2ft. square, and there must be step irons built in every fourth course of the brickwork. Junction manholes should be built L or T-shaped, with the shaft at the intersection of the chambers. Where the sewer is stepped the inlet sewer should not discharge at a high level into the manhole, but into a pipe shaft on the outside of it emptying on to the channel. At all important junctions of sewers storm overflows should be provided in the manholes, the height of these should be two-thirds of the diameter of the main sewer above its invert, and should have a fixed sill running the whole length of the side of the manhole; the apron of the weir should be tapered and arched over, and connected to a pipe discharging into an adjacent water-course. When a storm overflow is required on a high-level branch sewer a small chamber about 3ft. square should be formed clear of the drop shaft into the junction manhole, having a double invert with wall fixed between them, the invert of storm drain being below that of the sewer.

Lamp eyes may be of either brick, or pipe shafts surrounded by concrete; it is not expedient to use them at bends of sewers, but only at intermediate points on straight lengths.

FLUSHING.

It is important that ample provision should be made for the flushing of sewers; even where good gradients are the rule there should always be tanks at the dead end of sewers, as so many of them have not a sufficiently uniform volume of flow as to keep them self-cleansing, and where the

gradients are comparatively flat intermediate tanks should be provided. The sizes of these tanks must be determined by the capacity and length of sewer requiring to be flushed; the secret of good flushing is to have a sufficiently large volume of water discharged through the sewer, and at such velocity as to cleanse from its interior surface the deposit which is left by an abnormal flow, adhering above the usual dry-weather line. It is this deposit which is so dangerous, owing to the gas which is continuously given off from it Smells from sewers are unavoidable, but the nuisance from sewer gas may be very much minimised by a good system of flushing. The tanks should be fitted with an automatic flushing syphon, and the inflow of water can be regulated to the capacity of the tank and the periods of discharge desired. Where a free supply of water is not available, brooks, reservoirs, and ponds should be laid under obligation for the purpose, and where the supply is limited penstocks should be placed in the manholes at the head of the flat sewers, and if these are of abnormal length, at intermediate ones, so that the fullest use may be made of the flushing water.

VENTILATION.

The ventilation of sewers is a necessity, as too much fresh air cannot be supplied to them, and the more the sewer air is diluted the better, for it is indisputable that dilution by fresh air deprives sewer gas of its noxious properties, and if the current of sewage within and toward the outfall of the sewer be maintained without interruption, as it may and should be, time will not be afforded for dangerous decomposition being set up in sewers. The gases

from decomposing sewage are found to be marsh gas, carbonic acid, sulphuretted hydrogen and nitrogen. Sewer air contains oxygen, nitrogen, carbonic acid, and traces of sulphuretted hydrogen, marsh gas, and ammonia. It would only lead to confusion to draw attention to the investigations that have from time to time been made upon the conditions of the air found in sewers in this country by Letheby, Parkes, Burdon-Sanderson, Carnelly, Haldane, Parry-Laws, and in America by Nicholls. It may be taken that the tension of air in sewers is seldom very different from that of the atmosphere, or, if there be much difference, equilibrium is quickly restored. Many systems of ventilation have been tried from time to time, some involving elaborate mechanical and chemical appliances, which, under the conditions of working, speedily get out of order, and it is not necessary to explain the variety of expedients which have been resorted to in many towns to deal with the emanations arising from old defective and neglected sewers, nor with the causes — many of them very complex — which have created them, because similar conditions are not likely to be met with in villages, and especially in a new system of sewerage, which should be designed and worked under such supervision as to prevent their generation.

It is a common practice unfortunately to connect the rain water down pipes directly to the drains, and rely on them solely to act as ventilators to the sewers. This is a system which is universally condemned by all sanitarians. The heads of the pipes very frequently are adjacent to bedroom windows and other openings by which sewer air can enter the building. The pipes are invariably fixed close up to the face of the wall, consequently there is no joint at the back, or, at any rate, only an imperfect one, from

which sewer gas is also emitted. Again, when there is a sudden rush of surface water into the sewers, caused by a storm of rain, it is then that the air is displaced rapidly and seeks an outlet; and then, too, the rain water pipe is of least use for the purpose of ventilation, consequent upon its capacity being diminished by the passage down it of the rain water flowing off the roof. It is generally assumed that sewer air always passes uphill to the highest point from the lower parts of a drainage system, and that temperature is the only agent causing movements of sewer air, but its movement is too irregular to allow us to suppose that it can ever be got to move in a single direction.

Experiments were made at Wimbledon in 1888 by Mr. Santo Crimp, M. Inst. C.E., F.G.S., at that time Surveyor to the Local Board, and he trapped off a given length of 12in. sewer of regular gradient, and placed anemometers and self-registering thermometers at each end, which were read daily for twelve months. As a result of these experiments, Mr. Santo Crimp found that for all practical purposes the wind was the only agent producing movements of sewer air that could be measured by an anemometer, for when northerly winds prevailed the sewer air travelled up hill, and when southerly winds were experienced the sewer air passed down hill. In other sewers that were being experimented upon at the same time the opposite conditions prevailed; and this is easily explained, for in passing over a town the course of the wind is broken up and deflected, and it will affect the openings upon the sewers in different ways—in some cases inducing currents out of them, in others passing down into the sewers and driving out the sewer air elsewhere.

Mr. Santo Crimp ventures to formulate his views in the subjoined summary :—

(1) That the wind is the only agent which produces measurable movements of sewer air in an ordinary system of sewers.

(2) That the fullest use of the wind should be made in effecting the proper ventilation of sewers.

(3) That the offensiveness of sewer air should be lessened to the fullest practicable extent by systematic flushing and cleansing of the sewers, and by keeping them structurally in a thoroughly effective condition.

In 1891 the Birmingham Corporation by a special committee made some careful investigations upon this question, and the following extracts from their report to the Council may be of service :—"It is obvious that the generation of sewer gases cannot be entirely avoided, and your committee have, therefore, considered how the generation of sewer gas could be reduced, and how the gases generated could be disposed of with the least annoyance and danger.

"They are of opinion, that by more frequent flushing of the sewers, the sewers would be kept cleaner, and the arrest and subsequent decomposition of the sewage in the sewers would be reduced. With regard to the ventilation of the sewers, many plans have been tried, the most general being that adopted in this city, viz., by open shafts from the crown of the sewer to the crown of the roadway, with the addition in most instances of the gully drains.

Deodorisation of the gases by means of charcoal has been tried, but generally abandoned, the charcoal requiring frequent renewal or else becoming clogged, and preventing the free passage of the gases.

"Your committee have also tried, in two places where complaints were made of the escape of sewer gas, patent gas destructors, which consist of jets of coal gas surrounded by metal cones, placed in the bases of hollow columns; but the action of the apparatus is not sufficiently energetic, in the opinion of your committee, to justify the initial and annual outlay involved in the extension of the system.

"Upcast pipes, with cowls at the top, placed at the sides of buildings, have been tried in some places, particularly in Nottingham, and are said to work well. Several have been erected and tested by our city surveyor, who reports that he considers them good as supplemental to, rather than in substitution for, the open gratings at the road surfaces, and your committee propose to extend the use of such pipes in suitable directions.

"Your committee do not consider the plan adopted in some towns of utilising the rainwater down spouts as ventilators, is one that should be encouraged, as in their opinion it is one that is fraught with much danger to the public health."

It will be noticed that they state that the most general system is that of open gratings on the manholes, and a more recent report to the Ashton-under-Lyne Corporation, containing returns from over 100 towns, confirms this statement. The system will enable the sewers to breathe and ventilate themselves at all times, and when applied must be carried out in an intelligent manner, the gratings being placed at from 80 yards to 100 yards apart, care being taken not to place them nearer than six yards to any house, so that wherever the roads are narrow the ventilation should be by means of upcast shafts carried up the sides of the houses,

and not less than 6in. in diameter. The district should be divided, too, into ventilating zones, so that the smells created on a particular level should be confined to and dealt with in that area, the branch sewers from the higher levels being intercepted in the connecting manhole by means of a flap valve placed on the end of the inlet pipe, a fresh air inlet shaft being provided at the back of the chamber. There should be dirt boxes placed under all the gratings, and the scavengers on the occasion of their visits should be careful to clear the openings between the bars. It is no uncommon thing to see a district laid out on this system with the gratings all blocked with road detritus; it is from this want of attention, and the lack of flushing, and from so many of the manholes having deposits in the channels, that failure arises and complaints are uttered as to the nuisances which are created, and which are easily controllable under a proper system of construction and management.

If the little trouble of attending to this is considered as objectionable, it should be remembered that the system of sewering and house drainage is a hydraulic machine, and, like all other machines, requires at times an intelligent supervision.

PART IV.

SEWAGE DISPOSAL.

It is necessary, before sewage is discharged into streams, that it shall be purified, not clarified only—that is, that not only shall the matter in suspension be removed, but the organic impurities also, so that secondary decomposition shall not set up. The standard of purity which the effluent water should have has not yet been fixed. The

standard of the Rivers Pollution Commissioners was as follows :—

Maximum impurity permissible in 100,000 *parts by weight of liquid.*

Dry Mineral Matter in Suspension.	Dry Organic Matter in Suspension.	Colour.	In Solution.					
		Shown in a stratum of 1in. in a white plate.	Organic Carbon.	Organic Nitrogen	Any metal except Magnesium, Calcium, Blassium, or Sodium.	Arsenic.	Chlorine.	Sulphur as $S. H_2$ or Sulphate.
3	1		2	0·3	2	0·05	1	1

Standard of the Thames Conservancy Commissioners in parts per 100,000 :—Suspended matters, 4·3 ; total solids, 100·0 ; organic carbon, 3·0 ; organic nitrogen, 1·1.

The tests carried out at the Salford Works in 1891 of the various systems that were submitted showed the constituents of the sewage and effluents under the following nomenclature :—

Free ammonia.

Albumenoid ammonia.

Oxygen taken up in three hours.

Mineral matter in suspension.

Organic matter in suspension.

Mineral matter in solution.

Volatile matter in solution (loss on ignition).

An examination of the changes brought about in the albumenoid ammonia and oxygen taken up will disclose the percentage of purification attained. Albumenoid ammonia represents the nitrogen in organic matter which has not yet begun to decompose by oxidation, the nitrogenous matter

consisting of urea, uric acid, colouring matters of animal origin, mucus, and various bodies in a state of unstable equilibrium somewhat resembling albumen in their chemical characteristics.

The processes by which sewage can be purified are as follows :—

(*a*) By broad irrigation.

(*b*) By intermittent downward filtration.

(*c*) By precipitation in tanks and subsequent filtration.

It is not possible to deal with this subject exhaustively within a short space, and I only propose to point out the most salient features in each system, and for those who require more detailed information I would refer them to Mr. Santo Crimp's book on "Sewage Disposal" and the "Transactions of the Association of Municipal and County Engineers."

PURIFICATION THROUGH LAND.

For broad irrigation an area of land is required equal to 1 acre per 100 of the population, the surface having a gentle slope, preferably to the south. By irrigation is meant "the distribution of sewage on a large surface of ordinary agricultural land, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied."

The best kind of land is that which has a light, open, pervious soil, but not sand or gravel, and, on the other hand, not compact and retentive. When the sewage permeates through the soil its organic impurities are oxidised and destroyed, and the vegetation absorbs and assimilates a proportion of the organic matter present. The sewage should be conveyed over the land in open carriers or grips

following the surface contours, with shuttles at suitable points, so that it can be admitted on to the surface. Land carefully and intelligently farmed is very productive, but it is very questionable whether it can be made to pay much more than working expenses, leaving the interest and sinking fund on the purchase money a charge on the rates.

The other system of treating the sewage on land is by intermittent downward filtration, and for this method an acre is required for every 500 persons, the soil and site selected being similar to that for broad irrigation. The land for this process must be underdrained at about 6ft. deep, the surface being prepared in butts about 30ft. wide, with a gentle slope from the ridge along which the sewage is conveyed. Sometimes the land is laid out in ridges and furrows, the ridge about 2ft. wide, and the furrow 5ft., the sewage being poured into the latter and absorbed into the ridges. The distance apart of the main underdrains and the lateral branches must be regulated by the porosity of the soil, but it is not advisable at first to place them too close together, or the land would act like a colander. In small districts where this treatment is adopted, in the first instance it is better to collect the sewage—having previously strained it — into a meter tank having an automatic discharging syphon. This will prevent the evils which arise from a thin stream trickling along the carriers, and ensures more complete purification being attained.

Chemical treatment alone has not yet been successful in the purification of sewage, and subsequent filtration has to be resorted to; a combined method is the one that is most in favour at the present time, no doubt on account of its requiring so much less land for the purpose. The

rule of the Local Government Board is as a minimum one acre of land for 2000 persons for a filtration area clear of works, and for no process will they approve of less, not even for a successful mechanical filter like the Polarite of the International Company, which at present takes up comparatively little space.

TANKS.

The first stage in the combined treatment of sewage is subsidence in tanks assisted by a precipitant which should also be a deodorant. For some years lime has been largely used, but it is now admitted to be a failure in spite of its merit of cheapness. There are many precipitants manufactured, and great care should be exercised before adopting any one of them; the figures of percentages of purification sometimes claimed for them are apt to be misleading, unless the analysis of the raw sewage treated is obtained for comparison. Sewage is so fluctuating in quality, and the conditions of all places are not alike, so that what is suitable as a precipitant at one time and place would be quite useless at another, and before any precipitating agent is determined upon the strength of the sewage must be ascertained by analysis taken from frequent samples, so that the constituent parts of the material may be accurately fixed. The chief component of a good precipitant should be an efficient oxidiser, and the principle of oxidation is always involved; still there might be surrounding elements which would prevent that oxidation effectually taking place without such counteracting influences were negatived or neutralised. Those precipitants which contain a sufficient quantity of ferric-sulphate produce the best results in the opinion of Mr. Dibdin, the Chemist to the London County Council. The action of

precipitants upon sewage, and the chemical changes which ensue, will be found fully described in a paper read by Dr. Burghardt, before the Association of Municipal and County Engineers.* The precipitant may be added to the sewage either in solution or by means of a soluble cake like alumino-ferric or kremnolite ; the latter form is to be preferred for its simplicity and economy of working, no mechanical mixing machinery, with the necessary motive power, being required. Before the precipitant is added the sewage should be passed through strainers to arrest the heavier particles and the flocculent matter, and on its way to the tanks should pass along a mixing race, having baffling walls across the channel, so that the sewage and precipitant may be adequately incorporated.

Tank accommodation should be provided in the aggregate for at least 50 per cent. of the daily dry weather flow of sewage. The usual type of tank in this country is a rectangular shape, and from investigations made in Germany it is claimed that the best results are obtained from long, narrow, and shallow tanks. Mr. Santo Crimp recommends the tank space being divided into three, one of sufficient capacity to hold two hours' flow of sewage, a second to be used when one is cleansed, and a third for the normal rain water, and that each of these should be divided into three compartments by cross walls. The total length to be four times the width, the depth not exceeding 6ft. at the inlet end, and at the outlet 4ft. 6in. Floating arm outlets should be provided for drawing off the effluent, penstocks fixed in the cross walls to pass the sludge, which should be drawn out through a valve fixed in the floor at the inlet end,

* Transactions, vol. xviii., p. 306.

There should be vertical scum boards across the tanks placed a few inches from the cross walls. All the interior work of tanks should be faced with Staffordshire bricks, and all other details should be arranged, as the discretion and experience of the engineer dictate. Latterly other forms after the model of the vertical tanks at Dortmünd, and which had their origin in the Röckner-Rothe process, have been considerably advertised and pushed by the several companies working the patents; and although they have received the sanction of the Local Government Board for certain schemes, there has not yet been sufficient independent testimony as to their efficient and economical working to warrant a wholesale abandonment in all cases, and situations of the rectangular and horizontal tank.

Tanks may be worked either upon the continuous flow or quiescent system; in the former case the speed of the sewage is checked, so as to allow a sufficient time for the deposit of the solids in its flow through the tanks, and in the latter after a certain period of rest the water is drawn off. In both systems frequent cleansing of the tanks is necessary, so that the incoming fresh sewage shall not be mixed up with the grosser impurities of the decomposing sludge lying on the floor of the tanks.

SLUDGE.

In the continuous flow system the tanks should be cleansed about twice a week, and in the quiescent system after each drawing off of the tanks. This sludge from the bottom of the tanks should be swept into a sump, from which it must be forced to the place of ultimate disposal. Owing to the density of sludge, pumping is not a satisfactory method of lifting; and there has lately been designed by

Messrs. S. H. Johnson and Co., the well-known engineers of Stratford, a process which they call a pneumatic forcing system, the plant being simple in arrangement ; its first cost is low, it is also economical and expeditious in working, and well suited for small schemes of sewage disposal. This sludge from settling tanks is the concentrated essence of sewage, and is exceedingly foul, and it is necessary for it to be got rid of as rapidly as possible, so as to avoid the nuisance which would be caused by its accumulation. The quantity made will average about three-quarters of a ton per day per 1000 inhabitants, usually containing 90 per cent. of water (see Table No. 7). It may be disposed of by digging into the land or by running it into large lagoons, the supernatant water being drawn off and piped back to the tanks for re-treatment, and when the sludge has sufficiently dried it can be cut up with a tool and loaded into carts to be used as manure. In larger places where space is a consideration, and the works are adjacent to houses, the best process is to lift it into a filter press. This method rapidly reduces its bulk to one-fifth, but the cost is somewhat expensive, varying from 1s. 10d. to 2s. 6d. per ton of sludge cake produced. The filtrate water from the presses should be taken back to the tanks for re-treatment.

FILTRATION.

The chemical processes of treatment of sewage in tanks will clarify the sewage, and to some extent deodorise it, but only remove a small proportion of the soluble matters, thus not purifying it sufficiently to dispense with filtration of the effluent from them. According to Sir Robert Rawlinson this clarified sewage has seven-eighths of

the salts of sewage in it (all the dissolved impurities), when it is as clear as the cleanest water that can be obtained from a filter, and if passed into a shallow brook it would in summer ferment and become putrid and offensive. The tank effluent should therefore be applied to the land which has been obtained for the purpose, and which should be prepared and laid out on the lines of the intermittent downward filtration system already described. Where the land is particularly heavy and entirely unsuitable for the purpose specially prepared filters will have to be resorted to, and of these the Polarite filters of the International Company are unsurpassed in the excellence of the effluent water turned out from them. Good results can be obtained from filters composed of sand, gravel, and ashes, or coke breeze, but these, of course, require a great deal of attention and intelligent direction in the working of them.

Mr. Dibdin, the Chemist to the London County Council, for some time past has been making some exhaustive experiments in the filtration of sewage effluents, and his reports on that series is exceedingly valuable and instructive, and will well repay a careful study.* He found that sewage, "especially if previously clarified by precipitation, may be purified to any desired degree, the actual amount of purification depending upon (1) the length of time during which the effluent is allowed to remain in contact with the filter, and (2) the length of time allowed for aëration." In conclusion, he tells us "The action of a filter is two-fold, (1) it separates mechanically all gross particles of suspended matter, and renders the effluent bright and clear; (2) it

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* This report is printed *in extenso* in the *Surveyor* of November 1st, 1895

effects the oxidation of organic matters, both those in suspension and those in solution, through the agency of living organisms," and that "from the general results obtained by these several trials under various actual working conditions, it is apparent that there is no difficulty in obtaining any desired degree of purification by means of a system of filtration conducted on biological principles." The Salford Corporation have finally decided, on the advice of the Borough Engineer, Mr. J. Corbett, C.E., to filter the tank effluents through aërating filters, such as coke breeze, used intermittently with thorough drainage, and aëration in the intervals of rest at least once a day, the rate of flow not to exceed 1000 gallons per square yard per day while in use, and the filtering medium to be 5ft. deep.

The bacteriological aspect of sewage treatment is now receiving an increasing amount of attention, brought about no doubt by the publication of the results of the series of experiments made by the Massachusetts State Board of Health, and the researches of Pasteur and others. The purification is due to the action of the micro-organisms present in the sewage effecting its oxidation. At Dundrum Asylum a process is in operation arranged by Mr. Kaye Parry, C.E., on the method of supplying oxygen to the sewage in the tanks. Mr. Lowcock, C.E., has also had in work at Malvern some filters which are worked on the aëration principle, and which have produced remarkably good results, and which are both economical to lay down and to work. Both these processes are devised to assist the action of the microbes in the purification of sewage, and it is difficult to forecast what results may arise from the development of these systems. But, in conclusion, it must be borne in mind that the Local Government Board will not

approve of any mechanical or chemical process standing by itself, and that land must be obtained of a sufficient quantity to comply with their requirements.

Whatever system is adopted, it must be remembered that after it has been completed by the engineer, and he has gone his way, it will require careful and intelligent supervision and management. Probably the cost of doing this will amount to an annual charge amounting to a sum realised by a 2d. rate. This is often felt to be an irksome and unnecessary burden, and the works are neglected in the hope that they will proceed automatically, and failure in the management produces a crop of nuisances, the abatement of which entails unnecessary burdens, and often unpleasant litigation amongst neighbours. Results such as these are neither creditable to the wisdom nor business capacity of a Sanitary Authority, and are the inevitable consequence of neglecting the due care of the capital outlay upon which they have properly embarked for the furtherance of the health and convenience of their constituents.

ADDENDUM.

SPECIAL DRAINAGE DISTRICTS.

Since the matter on this subject, on page 15, has been in type, I have come into possession of a copy of a letter, addressed by the Local Government Board to a Rural District Council in Lancashire, in relation to the formation of Special Drainage Districts, and as their views are so fully set forth therein, and the instructions as to what is required

by them are so explicit, the publication of them here may be of great assistance to those who at any time may be called upon to deal with the question.

[COPY EXTRACT.]

Local Government Board,
Whitehall,
October, 1895.

Having regard to the fact that the Public Health Act, 1875, contemplates that in all ordinary cases the civil parish shall in rural districts be the area upon which special expenses incurred in respect of it shall be charged, it is contrary to the practice of the Board to approve of the constitution of a special drainage district under Section 277 of the Act, save in exceptional cases where the circumstances clearly point to the desirability of adopting such a course.

In this connection the Board point out that a special drainage district, if formed, becomes a separate contributory place for all the purposes of the Public Health Act ; in view of this fact the Board require in such cases to be satisfied (*inter alia*) that both the areas proposed to be formed into the special drainage district, and also the remainder of the civil parish, are areas of such a nature as to be suitable for special contributory places for the purposes of the Act.

Subject to the above conditions, the Board are prepared to entertain an application for their approval of the constitution of special drainage districts, in cases where it is proposed to carry out for the sole benefit of the area comprised in the proposed special drainage district, sanitary works involving a large capital expenditure.

In such cases, however, the Board only consider the application for their approval of the constitution of such special drainage district in connection with the application for their sanction to the raising of the loan required to defray the cost of the work proposed to be carried out.

The resolution of Rural District Council, constituting the

special drainage district, should define the district by reference to a 6in. Ordnance may of the parish, on which the area should be indicated by a hard line of colour. The map should be prepared in duplicate, each copy being endorsed, "This is the map" (or "a duplicate of the map," as the case may be), referred to in the resolution of the Rural District Council of passed on the day of , 189 , constituting the special drainage district. This certificate should in each case be signed by the Clerk to the Rural District Council, and both copies of the map should be forwarded with the copy resolutions. A statement should also be furnished giving the population and assessable value of the parts of the parish within and without the proposed special drainage district, and also the grounds on which the District Council support the proposal to set up a special drainage district.

TABLE No. 1.

Explanation of Words or Terms.

Sewage—The fluid and feculent refuse of dwellings.

Sewer—The main conduit for sewage.

Drain—The tributary conduit for sewage from houses to sewers.

Sewerage—A system of sewers.

Raw or Crude Sewage—Sewage as it flows untreated from a sewer.

Clarified Sewage—Sewage deprived of solids and flocculent matters.

Purified Sewage—Sewage filtered through land, or specially prepared media sufficiently to have neutralised the salts.

Tank Effluent—The water flowing from the tanks after precipitation.

Effluent Water—The water flowing from the filtration area or filters.

Sludge—The crude refuse from tanks.

Sludge Filtrate Water—The water pressed out of the sludge.

Supernatant water—The water overlying the sludge.

TABLE No. 2.

Showing Quantity of Rainfall per Acre.

Inches in depth of rain.	Cubic feet per acre.	Gallons per acre.
·1	363	2,262
·15	544·5	3,393
·2	726	4,524
·25	907·5	5,656
·3	1089	6,787
·35	1270·5	7,918
·4	1452	9,049
·45	1633·5	10,180
·5	1815	11,311
·55	1996·5	12,442
·6	2178	13,573
·65	2359·5	14,704
·7	2541	15,836
·75	2722·5	16,967
·8	2904	18,098
·85	3085·5	19,309
·9	3267	20,360
·95	3448·5	21,491
1·00	3630	22,622

TABLE No. 3.

When surface water is to be admitted into sewers, provision should be made for removing at the following rates per hour.

	Inches in depth.
From roofs...	·5
„ flagged surfaces	·2
„ paved „	·1
„ gravel surfaces with clay subsoil	·05
„ „ „ and subsoil...	·01
„ meadows or grass plots...	·02

TABLE No. 4.

The Discharge and Velocity of Sewers.—Beardmore's Formula.

$$V = C\sqrt{R \times 2H}.$$

V = Velocity in feet per minute.

R = Hydraulic mean depth.

H = Fall in feet per mile.

C = An empirical constant value 55.

$$D = V \times A.$$

D = Discharge.

A = Sectional area of pipe.

Formula used in "Surveyor" Tables.*

$$v = \sqrt{\frac{2gh}{1 + e + \frac{cl}{d}}}$$

h = head of water in feet.

l = length of pipe in feet.

d = diameter of pipe in feet.

v = velocity in feet per second.

c = coefficent for friction in pipe.

e = coefficient of resistance for entrance of water into pipe.

$g = 32{\cdot}2$. $\qquad c = {\cdot}01439 + \dfrac{{\cdot}016921.}{\sqrt{v}}$

e is at an average = ·505, but may by reduced to ·08 by rounding off the inlet.

For $h = v$, and $1 : i$ = rate of inclination, then

$$v = \frac{2g}{1 + e + \frac{civ}{d}}$$

---

* Tables of discharge at inclination from 1 in 5 upwards, calculated from this formula, are now published by St. Bride's Press, 24, Bride-lane, Fleet-street, E.C., prce 1s.

Ordinary sewage requires a mean velocity of 2ft. per second to keep the sewers clean. The gradients should never exceed for—

9in. pipes	1 in 450
12in. ,, ...	1 in 600
15in. ,, ...	1 in 700

TABLE No. 5.

Hydraulic mean depth = sectional area of sewage in the pipe, divided by the wetted perimeter, which is that part of the circumference in contact with the sewage. In circular pipes at varying depths of flow, the hydraulic mean depths are :—

Diam.	Full.	¾ Full.	⅔ Full. = ·61 of the diam.	½ Full.	⅓ Full. = ·39 of diam.	¼ Full.
9in.	·1875	·2263	·2183	·1875	·1396	·11
12in.	·25	·3017	·2911	·25	·1862	·1466
15in.	·3125	·3771	·3639	·3125	·2327	·1833

Sectional areas in square feet—

9in.	·4418	·3554	·313	·2209	·1289	·0864
12in.	·7854	·6318	·556	·3927	·2292	·1535
15in.	1·227	·9873	·869	·6135	·3581	·24

Wetted Perimeters in feet—

9in.	2·356	1·571	1·433	1·178	·923	·785
12in.	3·1416	2·095	1·911	1·571	1·231	1·047
15in.	3·927	2·618	2·389	1·964	1·538	1·309

TABLE No. 6.

Inches in decimals of 1ft.

12 inches	= 1·00	5 inches	= ·4166	¾ inches	= ·0625
11 ,,	= ·9166	3 ,,	= ·333	⅝ ,,	= ·0521
10 ,,	= ·8333	3 ,,	= ·25	½ ,,	= ·0416
9 ,,	= ·75	2 ,,	= ·1666	⅜ ,,	= ·0312
8 ,,	= ·666	1 ,,	= ·0833	¼ ,,	= ·0208
7 ,,	= ·5833	⅞ ,,	= ·0729	⅛ ,,	= ·0104
6 ,,	= ·5				

TABLE No. 7.

To ascertain Weight of Sludge.

Sludge from tanks contains water...	90 per cent.
,, ,, solids...	10 ,,
Of solids an average 33 per cent are organic.	
Draining will not reduce water in 48 hours to less than...	80 ,,
Draining will not reduce water in one week to less than	70 ,,
Exposure in thin layers on well drained surface will reduce it to	50 ,,

Let X = weight to be ascertained.
S = weight of solids in raw sludge.
W = percentage of water to be retained.

$$\text{Then } X = \frac{S \times 100}{100 - W}$$

Ex.—What will be the weight of 25 tons of raw sludge with 90 per cent. of water, when dried to 15 per cent.?

$$\text{The solids in the raw sludge} = \frac{25}{10} = 2{\cdot}5 \text{ tons.}$$

$$X = \frac{2{\cdot}5 \times 100}{100 - 15} = 2{\cdot}94 \text{ tons.}$$

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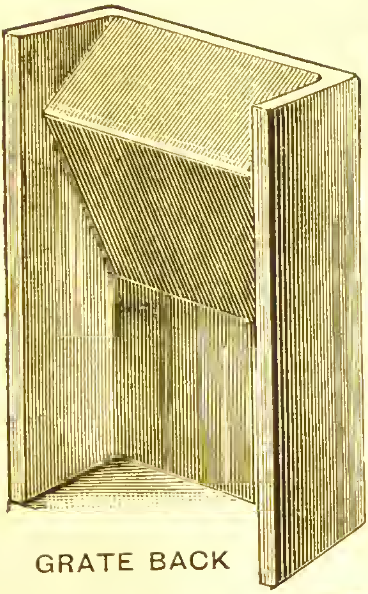

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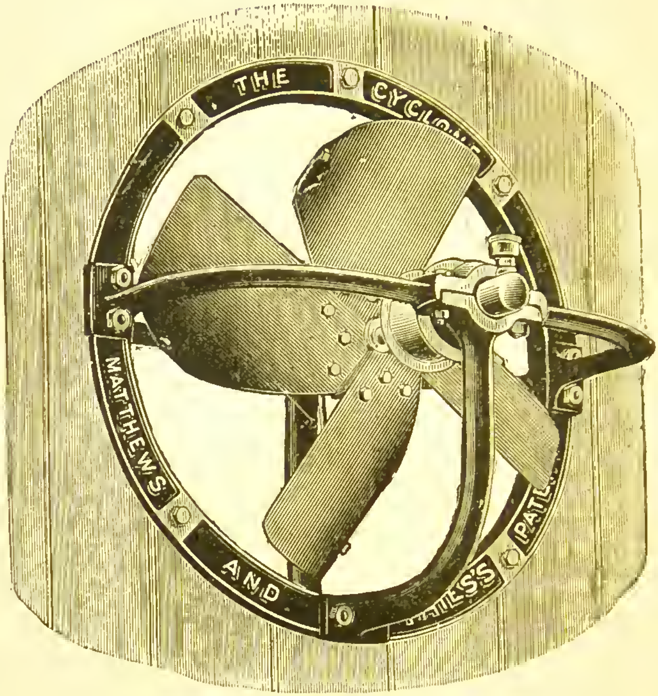

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